Research Article

Evaluation of water quantity–quality, floodplain landuse, and land surface temperature (LST) of Turag River in Bangladesh: an integrated approach of geospatial, field, and laboratory analyses

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Abstract

Rapid urbanization, industrialization, and development activities are posing numerous threats to the rivers of Bangladesh. In the recent decade, Turag River has been exposed to severe threats due to anthropogenic activities. The present research deals with the evaluation of water quantity–quality, landuse and landcover (LULC), and land surface temperature (LST) of Turag River and its floodplain by using an integrated approach of field study, laboratory analysis, and geospatial techniques. LULC mapping of the study area has been done using multi-temporal Landsat satellite images by unsupervised method, Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index indices (NDWI) approach. From LULC classification, the study shows that the average reduction of water bodies from 1989 to 2019 is about 60–66%, and the rate of reduction is about 14.25 ha per year. Due to anthropogenic activities and rapid urbanization, a large number of water bodies have been depleting. The average temperature of the river water from filed observed data is 30.23 °C and from image processed data is about 28.32 °C. The minimum and maximum values of pH, EC, TDS, and Eh are 6.87–8.44, 808–1192 µs/cm, 406–739 ppm, − 31 to − 150 mV, respectively. The concentration ranges of cations (Na, Ca, Mg, K, Fe, and Mn) are 85.43–247.60, 28.59–39.47, 11.1–13.58, 5.21–13.26l, .07–1.14, .006–.47 mg/l consecutively. The ranges of anions concentration (HCO_3^-, Cl^-, SO_4^{2-}, NO_3-) are 165.45–388.87, 54.81–194.07, 52.49–289.63, l9.63–126.93 mg/l, respectively. It is evident that HCO_3^-, NO_3-, and Mn exceed the standard limit of Bangladesh Water Quality Standard (BWQS) and World Health Organization (WHO), indicating that the water of the Turag River is deteriorating that is not safe for human consumption and aquaculture purposes. The study will assist to take some effective measures to control the pollution and uphold the water quality and natural riparian processes. So, the outputs of the study will contribute to the future urban landuse planning in the river floodplain area to mitigate ongoing alarming pollution and unplanned industrialization.

Keywords Water quantity · Water quality · Turag River · Satellite images · Landuse · Land surface temperature (LST)

1 Introduction

Geographically, Bangladesh is a riverine country with its major Ganges, Brahmaputra, and Meghna (GBM) river system. Except this, numerous small tributaries and distributaries of this major river system are draining throughout the country. River has a vital role in civilization, but unplanned urbanization has been playing a negative impact on the natural processes of rivers. Rivers in Bangladesh also serve people by providing waterways, energy sources, and agricultural activities.

Turag River is a vital channel flowing through the northwestern part of the megacity Dhaka that is geologically located on the south-central region of Madhupur tract and drains toward the southern part of the country [1]. The major landuse along the banks of the Turag River has been

used mostly for residential and commercial purposes, e.g., bazaars, markets, industries, warehouses, and hospitals. Residents adjacent to the river utilize the river water for swimming, washing, bathing, and boating both for recreation and communication. Water quality and quantity are being deteriorated due to the growing trend of industrialization in Bangladesh, as effluents from these industries discharge directly into the river without any treatment and environmental consideration [2].

A huge amount of industrial waste, sewage, and domestic waste have been dumped into Turag River regularly. Water quality of Turag River is greatly impacted by different industrial discharges including organic and inorganic effluents that interact with river water. This discharge plays an adverse impact on the livelihood of the local community, adjacent landmass, and aquatic ecosystem [3], [4]. Department of Environment [5] declared Turag River as an ecologically critical area (ECA). Whitehead et al. [6] disclosed that Turag–Tongi–Balu River system in Bangladesh is one of the most polluted ones in the world.

Rapid unplanned industrial growth and poor river management practice have been impacting the quality of river water in Bangladesh. Currently, numerous researches have been undertaken to monitor and assess the water quality of different Rivers in Bangladesh [7], [8], [9], [10]. Haque et al. [11] used a metal pollution index to assess the water quality of the Ganges River, Bangladesh. Kabir et al. [12] employed a water quality index along with a statistical approach to evaluate spatiotemporal variations of water quality in the Shitalakhya River, Bangladesh. Islam et al. [13] have investigated the origin and distribution of trace elements in six major river basins, Bangladesh. Nowadays, the issue of the impacts of industrialization on the surface water quality has drawn attention to the researchers of Bangladesh.

Few works have been done by in situ and laboratory analysis of water quality in Turag River. No study conducted using satellite images combined with the laboratory and in situ data. Remote sensing tool is very popular nowadays for environmental monitoring throughout the world. Lee et al. [14] conducted a study on the applications of remote sensing techniques to relate landscape and landuse patterns in watersheds to water quality in South Korea. Zhao et al. [15] documented the LULC influences on water quality in a riverine area near Shanghai, China. Qiao et al. [16] extracted water bodies completely and accurately from the remote sensing image. McFeeters [17] used multi-spectral imagery to denote the presence of surface water by remote sensing techniques.

Nowadays, evaluation and monitoring of the water body and its surrounding area by remote sensing techniques are very popular [18], [19], [20], [21]. Chawla et al. [22] reviewed the use of remote sensing techniques for

water security to enhance environmental protection and strengthen water resource management. Shen et al. [23] evaluated the linkage between landscape characteristics and nonpoint source pollution in an urbanized watershed. Tan et al. [24] monitored LST and LULC spatial relationships adjacent to the water body. A precise water quality analysis was done by Somvanshi et al. [25] in Gomti River, Uttar Pradesh. LULC is an important parameter to monitor environmental health in any region [26]. LST in urban areas along with near flood plain areas is a concerning issue for the environmentalist. Recently, several studies focused on the LST of different areas of Bangladesh to monitor spatiotemporal changes [8], [9], [27], [20], [28].

In Bangladesh, surface water quality especially in and around urban areas is deteriorating. Several pieces of research throughout the world concentrated on the surface water security of Bangladesh [29], [30], [31]. Researchers in Bangladesh also played a major contribution to the surface water extent, quality, and quantity monitoring. Water quality mainly traces metal concentration, origin, and distribution of six major river basins of Bangladesh rigorously studied by Islam et al. [13]. Whitehead et al. [32] modeled heavy metal pollution impacted by tannery waste in the Buriganga River system, Bangladesh. Mobin et al. [33] assessed the water quality of the Turag River, Bangladesh, showing the concentration of different physicochemical properties. Aktar and Moonajilin [34] tried to show the impacts of industrial effluents on water quality of Turag River, Bangladesh. Zakir et al. [35] evaluated the pollution due to heavy metals in the waters of Midstream of Karatoa River, Bangladesh. Hydro-environmental pollution of Turag River in Bangladesh rigorously carried out by Islam et al. [36]. Zaman et al. [6] determined the landuse effect on the Turag River water quality. Variation in the water quality of Turag River due to seasonal changes was rigorously studied by Rahman et al. [4].

The study of water quality and quantity of Turag River is very crucial due to the remarkable role of the river in the economic development of Bangladesh like other urban rivers in Dhaka city. Besides, floodplain dwellers are solely dependent on the Turag River for irrigation, drinking, and fishing along with other household activities. The combined approach of remote sensing, field, and laboratory analyses provides a clear scenario of the present status of water scarcity, pollution, and future existence of Turag River. Here, remote sensing data have enabled the study to depict the spatiotemporal changes of the Turag River water and its floodplains landuse and LST. Then, water samples analysis in the laboratory provides the current status of Turag River water quality. Finally, field observations helped to assess the present status of the River and the accuracy of remote sensing study. Water quality is directly related to the LULC of the River floodplains. Similarly, LST

provides a clue to the environmental deterioration around the floodplains. Hence, integration of the three methods certainly a novel approach to evaluate the water quality–quantity of the River. So, the prime objective of this study is to investigate and monitor the changes of water bodies, LULC surrounding the Turag River, and land surface temperature in and around the river both the quality and quantity of the Turag River using multi-spectral Landsat satellite images from 1989 to 2019.

2 Study area

Turag is known as an upper tributary river of the Buriganga, originates from the Bangshi River flows through Gazipur, and meets the Buriganga at Mirpur [37]. The investigated area of Turag River extends from Aminbazar, Savar Upazila to Tongi in Gazipur to Dhaka, Bangladesh (Fig. 1). It is one of the major natural drainage systems in the Gazipur and Dhaka city and one of the most contaminated rivers in Bangladesh having a length of 62 km, and average width is 82 m. The river is draining a part of the Pleistocene terrace, known as Madhupur tract that consists of alluvial soil, mottled red clay [38].

The area, especially river flood plains, is occupied by numerous garments, leather, and food industries, where effluents are discharged by abundant canals into the river. The major sources of pollution in Turag River are garments industries, various consumer goods, tanneries, pharmaceuticals industries, dyeing industries, battery manufacturing, textile, pulp and paper factories, paint, frozen food factories, and chemical factories [39].

3 Materials and methods

The study has been performed by a combined approach of field data collection, laboratory analysis, and satellite image-based interpretation. The methodology can be segmented into two-part, satellite image-based analysis, and field-laboratory-based analysis.

3.1 Satellite image-based analysis

Five sets of multispectral satellite images of 1989, 2000, 2009, 2015, and 2019 have been collected from the United States Geological Survey (USGS) archive (https://earthexplorer.usgs.gov/) (Table 1). For the processing, analyzing, and interpretation of satellite images, geospatial software Erdas Imagine 14 and ArcGIS 10.2.2 have been used in the research. For water quantities monitoring, three classification approaches have been used to prepare LULC of the study area. The approaches

are the unsupervised classification method using Iterative Self-Organizing Data Analysis Technique or ISO-DATA, indices based LULC classification, viz. NDVI and NDWI. These three different classification approaches have been used due to the object-oriented accuracy level. Here, unsupervised classification provides a generalized thematic information class in the study area. The NDVI indices emphasize the vegetation changes that have been used to observe the spatiotemporal variation in vegetation cover. Besides, NDWI indices have been used to evaluate the changes in the water bodies in and around Turag River. The combination of three provides a conspicuous picture of the total LULC changes in the study area. To monitor the remote sensing-based water quality and adjacent flood-plain area, LST has been retrieved for the selected years (Fig. 2).

NDVI has been calculated utilizing the following equation [40]:

$$NDVI = \frac{NIR - RED}{NIR + RED} \tag{1}$$

where NIR = reflectance value in near infrared region; RED = reflectance value in red region

The NDVI value ranges from -1 to $+1$. The densely vegetated region shows positive values around $+1$, whereas water body shows value close to -1.

NDWI has been calculated using the following equation defined by McFeeters [41]:

$$NDWI = \frac{GREEN - NIR}{GREEN + NIR} \tag{2}$$

where GREEN = reflectance of green region; NIR = reflectance of near infrared region

The NDWI values also range from -1 to $+1$. Positive values signify water features, while vegetation and soil typically show zero and negative values.

3.2 Field-laboratory analysis

To assess the in situ water quality of Turag River water, several physicochemical parameters and major ions have been studied in the hydro-geochemistry laboratory, Department of Geology, University of Dhaka. A total of 14 water samples were collected with GPS locations from the Turag River by boat. To meet this purpose, in situ pH, Eh and temperature have been recorded with a HANNA pocket pH meter (model HI 98127). Electrical conductivity and total dissolved solids (TDS) have been measured with an OAKTON waterproof pocket pH-EC comb Meter (model PC tester 35). Cations (Na^+, K^+, Ca^{2+}, Mg^{2+}, Fe, and Mn) and heavy metals are identified by atomic absorption spectrometer (AAS) (GBC SensAA) and anions (Cl^-, NO^{3-},
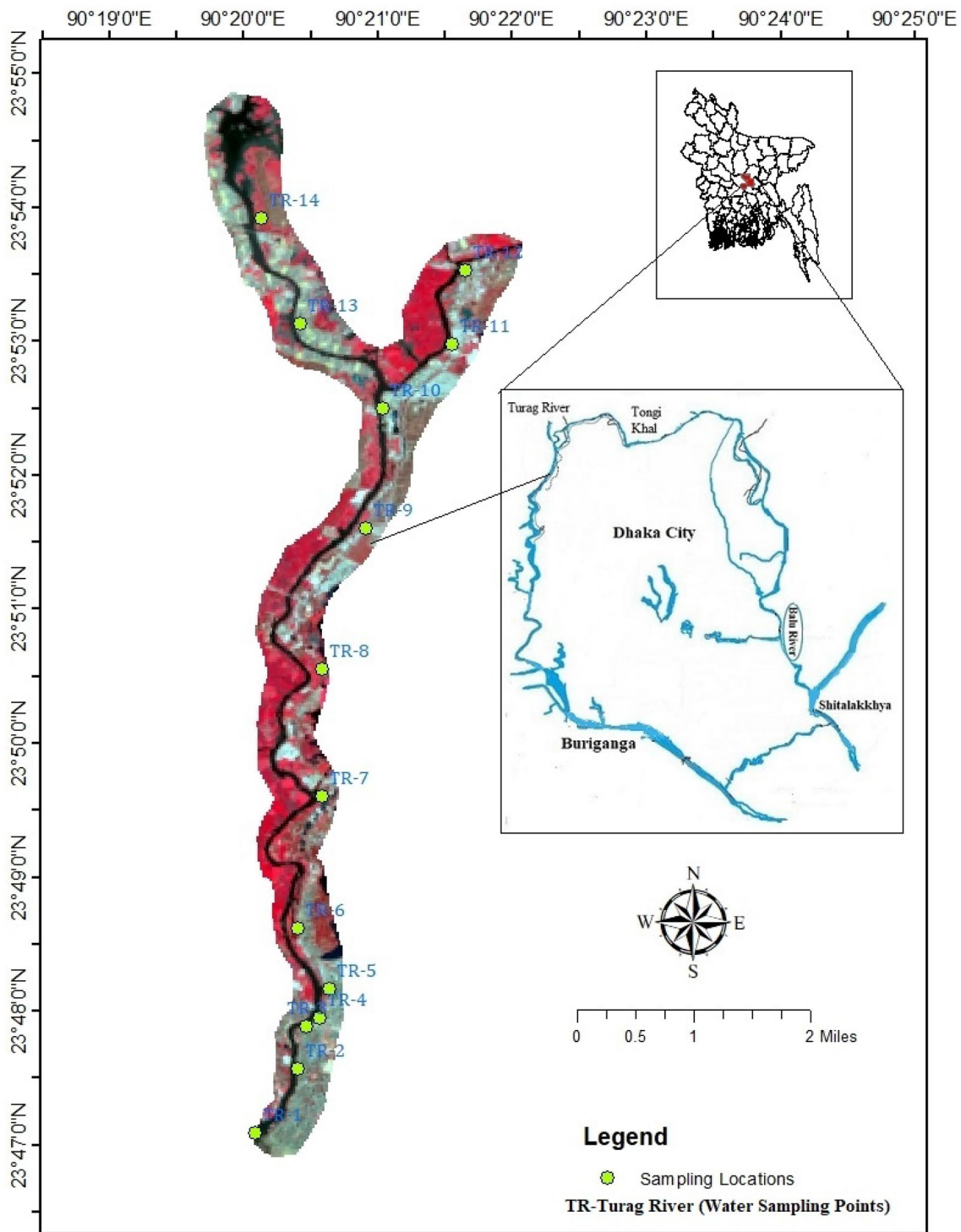
Fig. 1 Location and extent of the study area. The background is the band combination of Red: Green: Blue = Band 5: Band 4: Band 3 of Landsat 8 images dated 2018

SO_4^{2-}, F^-, Br_-, and PO_4^{3-}) by ion chromatography system (DIONEX).

3.3 Accuracy assessment

To determine the accuracy of the retrieved LULC classes from the satellite images, an accuracy assessment has

Table 1 Satellite images specifications with their acquisition dates

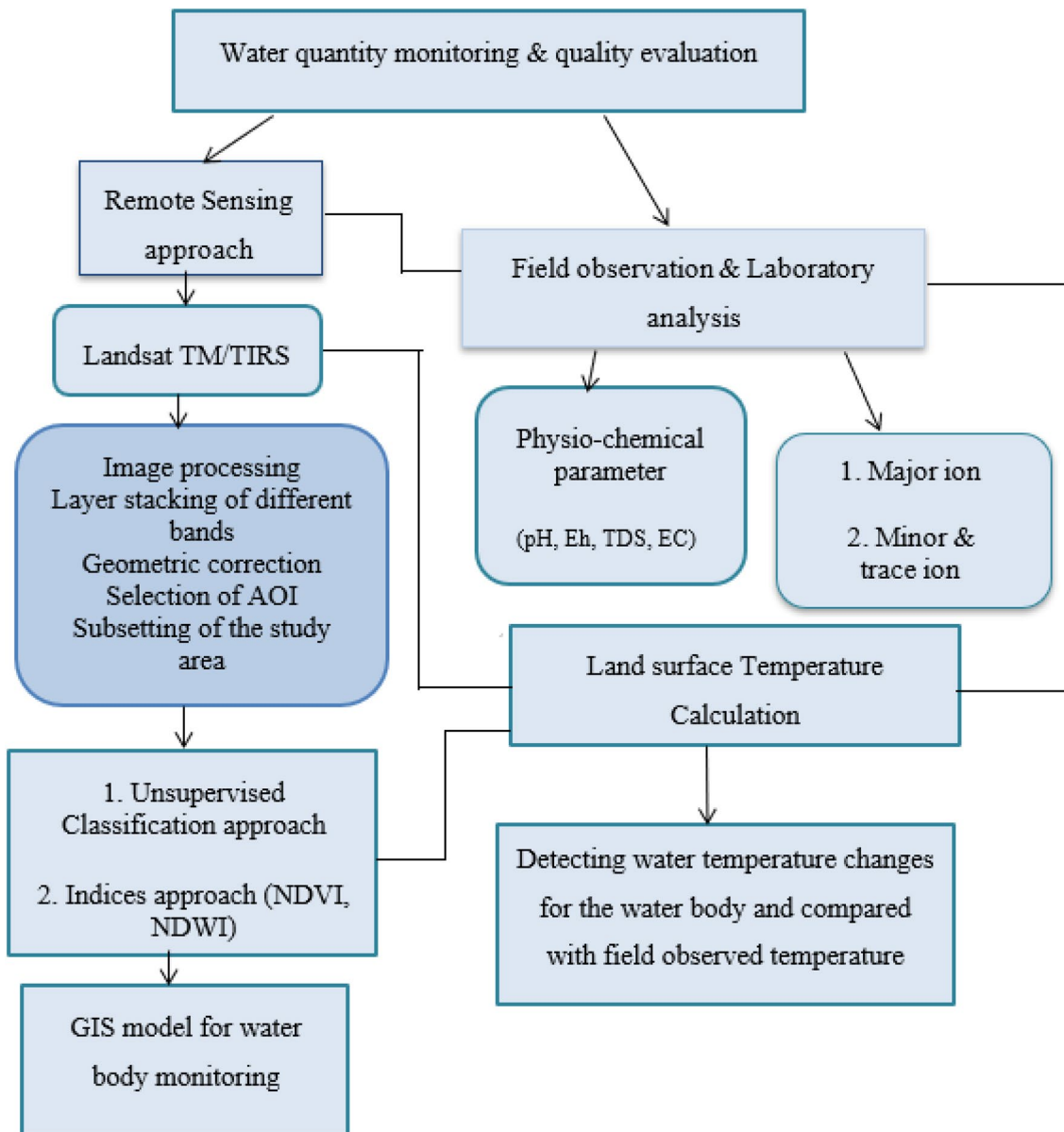| Sensor platform	Projection	Acquisition date	Resolution of used bands	WRS path and row
Landsat 5 (TM)	UTM, Zone 46 WGS 84	09 /03/1989	30	137/44
	UTM, Zone 46 WGS 84	19/01/2000	30	137/44
	UTM, Zone 46 WGS 84	28/02/2009	30	137/43
Landsat 8 (OLI/TIRS)	UTM, Zone 46 WGS 84	17/03/2015	30	137/43
	UTM, Zone 46 WGS 84	24/02/2019	30	137/43

Fig. 2 Methodology flowchart of the study

been performed. The ground observation data with the observed LULC have been taken as reference data. The unsupervised classified image of 2019 has been

compared with these ground truth data. The observed point's coordinates have been converted to ASCII format, and each point is compared with the reference value of

the classified image of 2019. Overall average classification accuracy is about 86.67% determined from the kappa statistics value.

Accuracy assessment has also been done for satellite-based LST measurement. Here, field measured values compared with all satellite images retrieved LST for the year of 2019. The water temperature of in situ measurements has been compared with the satellite image-retrieved LST and found a similar trend among 14 ground observation points of the Turag River. Satellite image-retrieved LST data values were lower than field observed in situ LST because the satellite images are medium resolution (resampled 30 m) and always give an average pixel value.

4 Results and discussion

4.1 Landuse-landcover (LULC) mapping

4.1.1 LULC by unsupervised classification approach

A total of five LULC classes of the study area have been classified such as water bodies, vegetation, bared, and urban area. From unsupervised classification, it has been identified that water bodies reduced about 50% from 1989 (about 405 ha) to 2019 (about 205 ha). There has been a gradual decrease in the water bodies from 1989 to 2019 (Fig. 3). There are two probable reasons for the reduced water bodies on both sides of the Turag River during the study period such as (1) filled up and development for the housing project, and (2) conversion of those water bodies
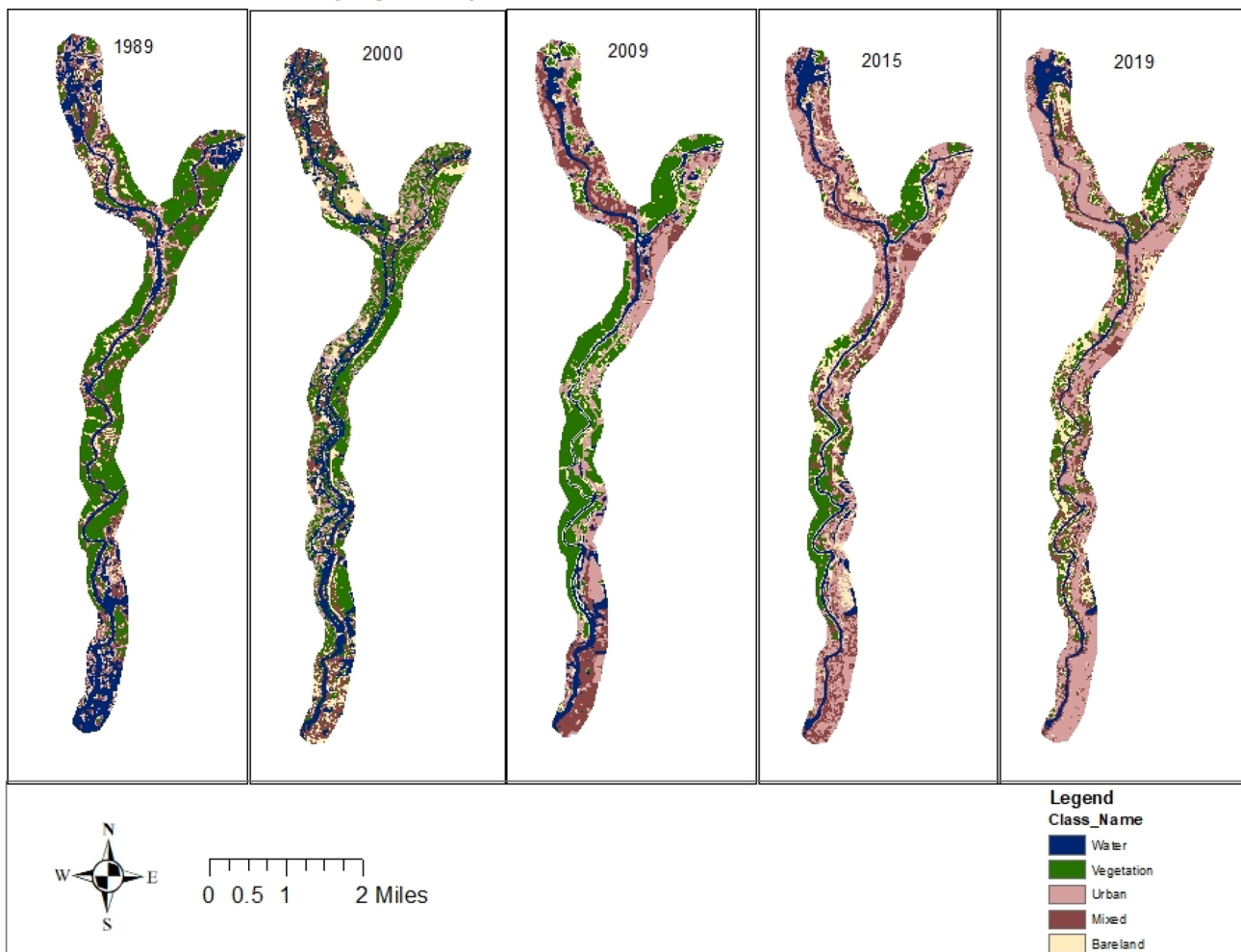

Fig. 3 Spatial distribution of LULC from 1989 to 2019 by Unsupervised Classification Approach

into agricultural land due to reduced water flows or other development activities like brickfield.

There had also been a rapid degradation of vegetated lands throughout the study period. Vegetation cover reduced gradually more than 50% from 1989 (600.53 ha) to 2019 (242.72 ha). The losses of vegetation are very acute at Savar, Ashulia, Tongi, and its adjoining areas. The different housing projects have been extended to these areas. With time, Tongi and Ashulia have become industrialized areas, and that results in the loss of vegetation in these areas significantly. Toward the northeast, some parts of vegetat cover have also been lost over years. Besides, small-scale vegetation losses have been seen in different parts of the river.

The urban areas were increased about three times from 1989 (209 ha) to 2019 (589 ha). It is clear that, in 1989, the urban growth was in the northwestern part of the Turag River as a mostly industrialized and commercial zone. Then, the urban growth has been expanded toward the eastern part of the Turag River. In 2019, urbanization has reached the furthest part of the eastern and northern parts of Dhaka city, which are mostly encroaching the areas surrounding the rivers Fig. 4. As the developed areas were mostly vegetated and wetlands earlier, so, this kind of unplanned urbanization has greatly degraded the living condition as well as the ecosystem of the surrounding rivers of Dhaka city.

Bhattacharya et al. [42] found a similar trend using unsupervised classification techniques that shows rapid

urbanization replacing huge vegetated area and bare land in and around Dhaka city. Shapla et al. [43] inferred that the local economy especially unplanned urban and industrial development significantly facilitates the reduction of huge agricultural land in Gazipur which is very close to the study area. Mahmud-ul-Islam [44] conducted a similar study in the Buriganga river which is also located in Dhaka city concerning LULC and water management issues for ensuring a sustainable environment. He reported that the Buriganga River is becoming extremely polluted owing to the careless dumping of industrial effluents, and household waste claiming the rapid industrialization and urbanization. Turag and Buriganga are the most vulnerable urban rivers in Bangladesh.

4.1.2 LULC mapping based on NDVI

From the NDVI thematic classified maps, it has been identified that the vegetation was reduced by about 60% from 1989 (about 858 ha) to 2019 (about 346 ha) in the study area. There was a gradual decrease in vegetation cover from the year 1989 to 2019 Table 2. Vegetation cover toward southwest and southeast near Savar, Aminbazar bridge, Mirpur road, and other low-lying areas have suffered much destruction Fig. 5. These areas were marshy, grasslands where housing projects have been developed to meet up the extended population Fig. 6. Toward the northwest and northeast part of the river near Ashulia, Tongi, and Uttars, vegetated areas have also been reduced with similar scenarios due to urbanization. Trotter et al. [45] determined the effects of rapid urbanization in Dhaka megacity using NDVI-based LULC. He found a close relation between decreased vegetation and increased urbanization. Singh et al. [46] utilized NDVI-based LULC classification approach in lower Assam, India. He pointed out that a significant amount of forest degraded due to urbanization. The present study also suggests the simultaneous increase of urban areas and the decrease in vegetation cover.

4.1.3 LULC mapping based on NDWI

Results from NDWI analysis show that the water bodies are reduced gradually by about 65% from 1989 (765 ha) to 2019 (about 267 ha) Table 3. From the thematic NDWI map of 1989, it is identified that there is huge water near

Observation of changes of Landuse-Landcover
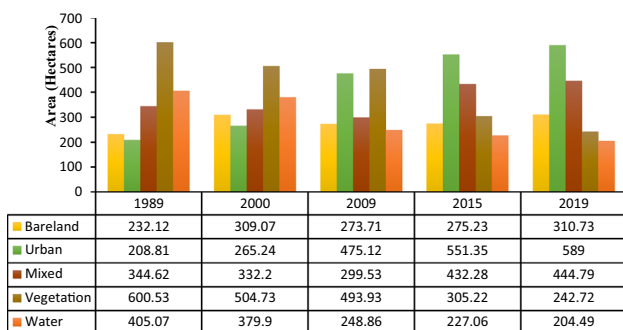1989,2000,2009,2015,2019

	1989	2000	2009	2015	2019
Bareland	232.12	309.07	273.71	275.23	310.73
Urban	208.81	265.24	475.12	551.35	589
Mixed	344.62	332.2	299.53	432.28	444.79
Vegetation	600.53	504.73	493.93	305.22	242.72
Water	405.07	379.9	248.86	227.06	204.49

Fig. 4 Histogram distribution showing the changes in LULC of the study area from 1989 to 2019

Table 2 Summary results of area coverage of LULC classes based on the NDVI of the study area from 1989 to 2019

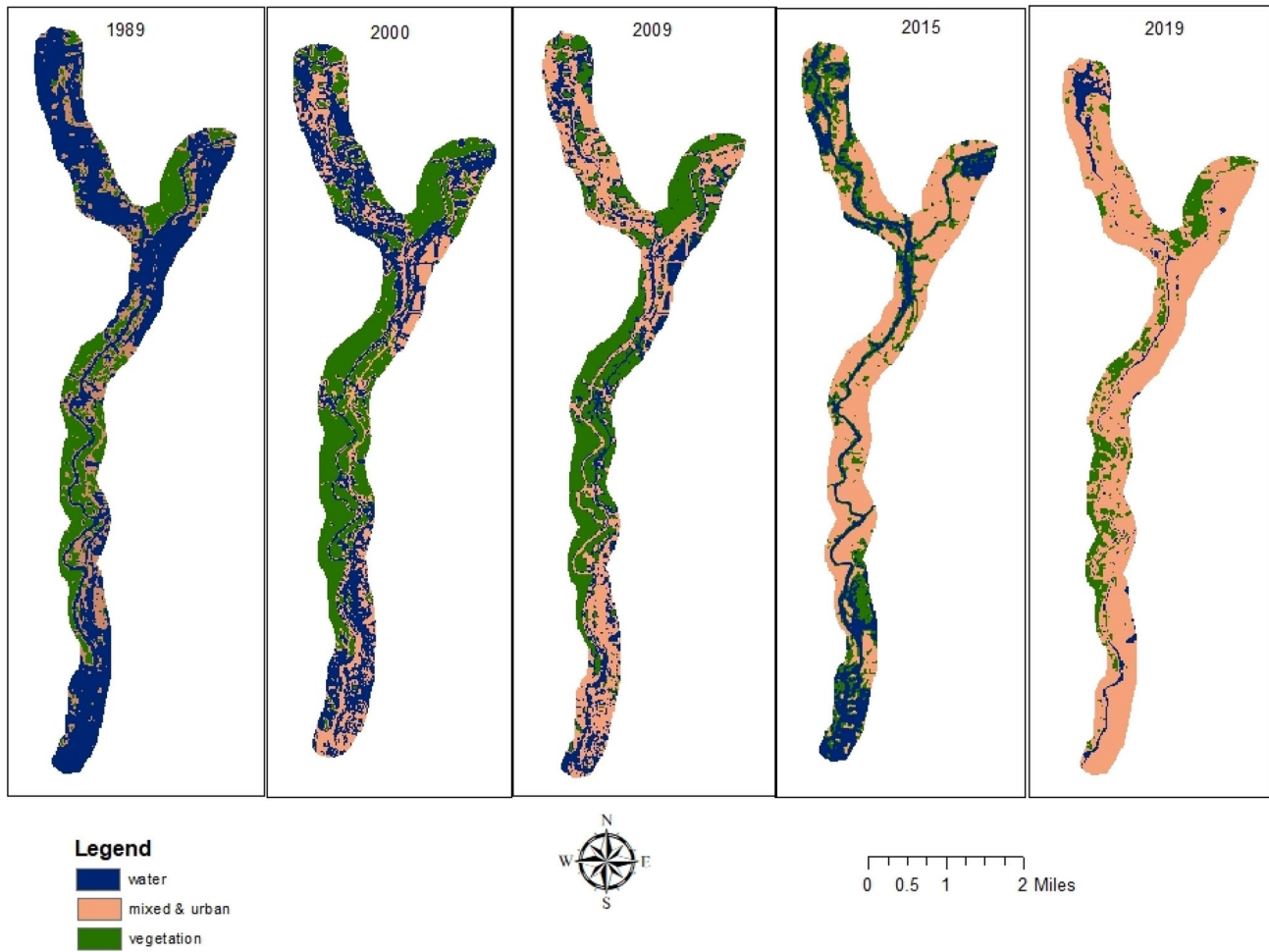| Class name	1989		2000		2009		2015		2019	
	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
Land	1026.27	57.29	1266.01	70.68	1414.16	78.95	1473.39	82.29	1524.49	85.1
Water	764.91	42.7	525.71	29.31	377.02	21.04	317.19	17.71	266.69	14.89

Fig. 5 Spatial distribution of LULU based on NDVI from 1989 to 2019
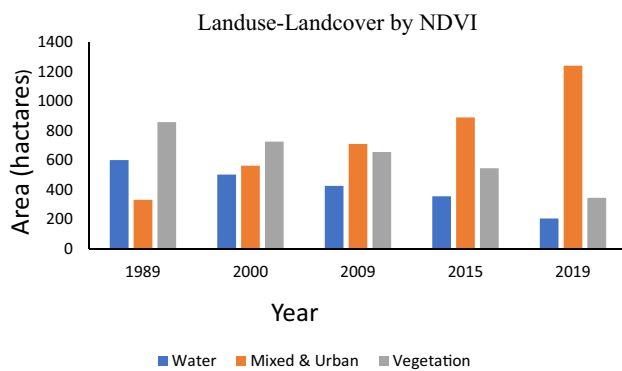

**Fig. 6** Area coverage of LULC based on NDVI from 1989 to 2019

to Ashulia western part of the Turag River. At that time, the water bodies are also significant at Savar near to Gabtoli bridge where Turag River joins with Buriganga river

Fig. 3. In 2000, water bodies have been decreased rapidly. In 2019, the water bodies of the Turag River reduced in a great amount about 65% from 1989 to 2019 Fig. 7. The study suggests that the Turag River has dried out mostly in 2019 in comparison with 1989 Fig. 8. Rapid urbanization is the main cause of this reduction of water. In course of time, many industries have been built up at Savar, Ashulia, and Tongi, which is the possible reason behind the reduction of the water bodies of the Turag River. Results of all three methods show that the water bodies have been declined significantly about 60–66% Fig. 9.

Ullah and Enan [47] used NDVI and NDWI index for mapping water bodies and vegetation cover in Dhaka city. They found that from 1991 to 2016 built-up area increased 120 Km^2 with a simultaneous reduction of about 82 Km^2 water bodies. Mia et al. [48] also suggested identical findings in their research conducted in Dhaka city by NDVI indices. Gazi et al. [49] used NDWI

Table 3 Summary results of area coverage of LULC classes based on NDVI of the study area from 1989 to 2019

Class name	1989		2000		2009		2015		2019	
	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
Water	600.78	33.54	502.93	28.07	425.65	23.76	255.23	19.83	205.24	11.45
Mixed and Urban area	332.21	18.54	562.67	39.62	709.75	39.62	890.1	49.69	1240.31	69.24
Vegetation	858.19	47.68	752.58	40.51	655.85	36.61	545.85	30.47	345.63	19.29
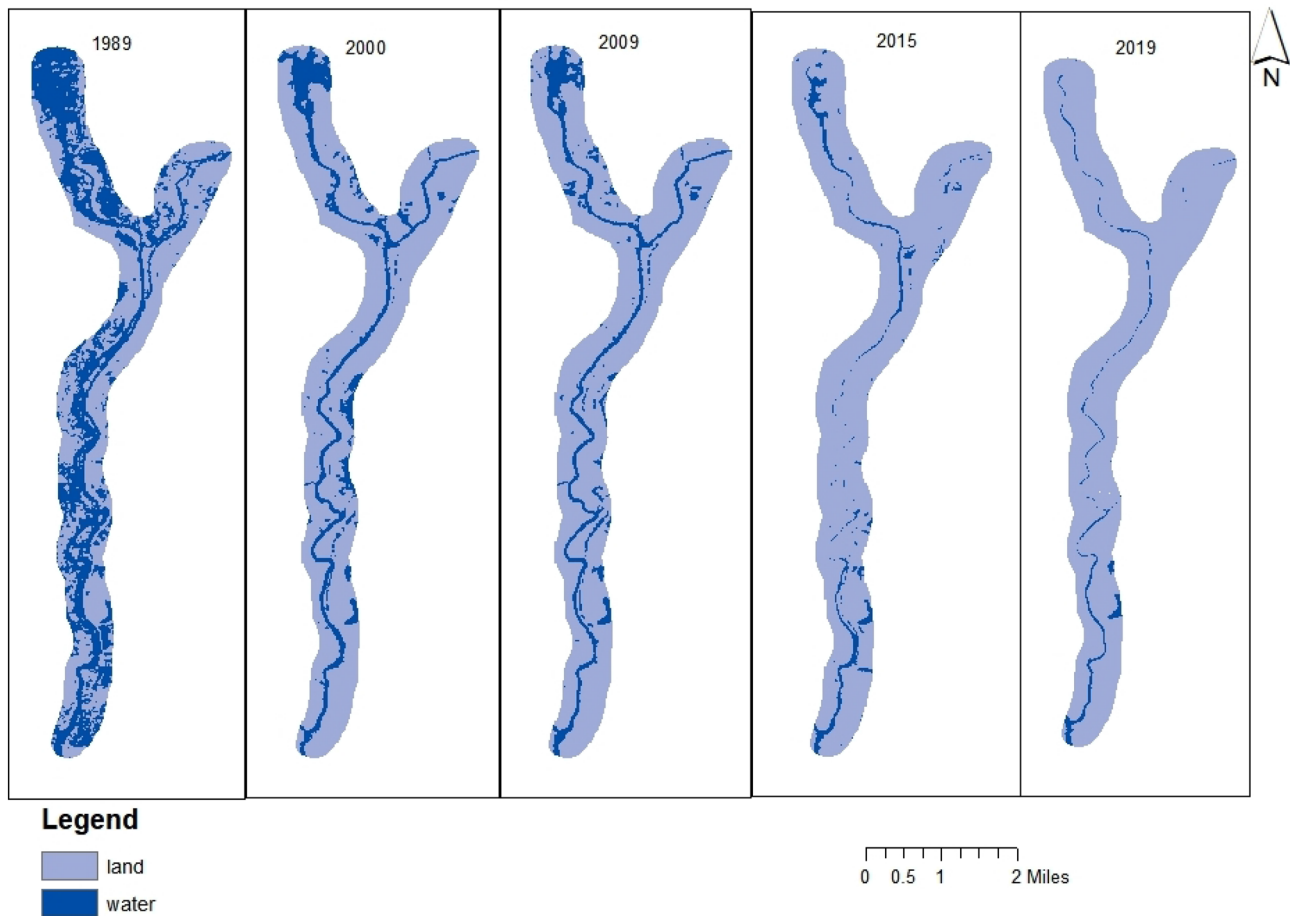
Fig. 7 Spatial distribution of LULU based on NDWI from 1989 to 2019

indices for mapping LULC for the last 47 years around two major river confluences in Bangladesh and found a significant decrease in water bodies around the confluences. The present study has utilized unsupervised, NDVI, and NDWI classification and compared the results to achieve maximum accuracy of LULC classification.

4.2 Water quality analysis

4.2.1 Physical properties of water

The pH value of collected surface water samples ranges from 6.87 to 8.44. The average pH value is 7.54. The lowest

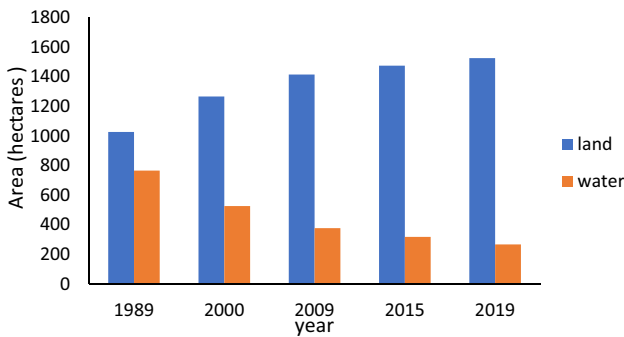## observation of LULC by NDWI classification of 1989,2000,2009,2015,2019

Fig. 8 Comparison of LULC classes based on NDWI from 1989 to 2019

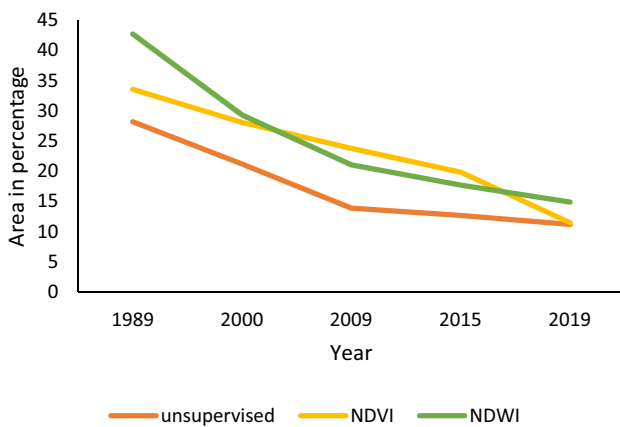## Changes of water bodies by Unsupervised, NDVI, NDWI

Fig. 9 Changes of water bodies among various methods out of the total study area

pH is near Gabtoli Bridge Ghat 6.87 and the highest value is near the Rupnagar bus stand which is 8.44 Table 4. For inland surface, water pH standard limits are 6.5–8.5 [50]. The field observation shows that the pH value of the Turag River is within the standard limit. Halder and Islam [51] documented pH ranged from 6.14 to 8.79 which is close to the pH obtained by the present study.

EC value of the Turag River is 808 to 1192 µs/cm. The average value of EC is 1062.14 µs/cm. The highest value of EC is 1493 µs/cm which is near Ashulia Chowrasta. The lowest value of EC is 808 µs/cm which is near to Rupnagar bus stand (Table 4). For inland surface water, standard electrical conductivity is 1200 µS/cm [52]. The flow of the river increases in the monsoon season, which may dilute the river water, whereas in the dry season, the flow of the river declines which increases the EC. The samples

have been collected in pre-monsoon (March), so the EC of the samples is high. Industries discharge into the river is responsible for high EC.

The measured Eh value from upstream to downstream is − 31 to − 150 mV. The average value of Eh is 104.78 mV. The highest value of Eh is − 150 mV which is near Ashulia Bridge, and the lowest value is − 28 mV near the Rupnagar bus stand. The pH and EC are very close to the range obtained from the study [4]. The study documented the pH value ranged from 6.60 to 7.98 and EC from 160 to 1107 µs/cm. He found the ranges due to seasonal variations in the study area. After all, he also suggested that the Turag River water is not suitable for human consumption.

The TDS values of the Turag River from upstream to downstream are 406 (ppm) to 739 (ppm). The average value of TDS is 551.21 (ppm) (Table 4). The highest value is close to the Ashulia bus stand, and the lowest value is near to the Rupnagar bus stand. TDS standard for domestic water supplies is 500 ppm by USPH, for drinking water is 1000 ppm, irrigation is 2000 ppm, and for industrial water is 1500 ppm [53]. So, the TDS of Turag River water for domestic uses and drinking purses is at an alarming range. This alarming increase of TDS value was also reported by Meghla et al. [3] and Mobin et al. [33]. Halder and Islam [51] also found a higher TDS value that exceeded the standard permissible limit.

Based on the observation from 14 sampling locations, the highest water temperature has been recorded at 32.80 °C and the lowest temperature is about 29.10 °C and the average temperature of 30.05 °C. The increasing temperature is due to the cooling operations for the manufacturing of products by the industries besides the Turag River. Several studies reported that the quality of Turag River water is not within the acceptable limit for drinking and agricultural works [54], [3], [33]. Water quality analysis suggests that the Turag River is in danger due to industrial pollution [29]. Aktar and Moonajilin [34] indicated that Turag water pollution is at a critical point. Impacts of indoctrination and urbanization on the water quality has also been observed from recent studies in Bangladesh [55], [56], [57]

4.2.2 Ion chemistry investigation

The study confirming the consistency of the analytical results of ionic balance between cations and anions as it is within the acceptable limits (less than 10%). Among the cations, Na+ is dominant and the concentrations range between 85.43 and 247.60 mg/l with a mean of 172.91 mg/l (Fig. 10). The higher concentration of sodium may result due to the mixing of sodium-rich effluent from chemical, food, tannery, and leather industries. According to BDWS [58], the standard value of Na+ is 200 mg/l,

Table 4 Showing the parameters describing physical properties of the Turag River water in different sampling points

Sample name	Location	pH	EC (µs/cm)	Eh (mV)	TDS (ppm)	Temperature (°C)
TR-1	Gabtoli Bridge Ghat	6.87	1192	− 93	597	29.6
TR-2	Palpara Ghat	7.29	1154	− 124	576	30.6
TR-3	Diabari Ghat	7.52	1123	− 107	562	29.5
TR-4	Shahi Jama Masjid Nawaberbag	7.40	1130	− 142	563	30.3
TR-5	Royel City Jame Masjid	7.54	1147	− 117	573	30.5
TR-6	Dakshin Para Jame Masjid	7.46	595	− 122	1192	30.7
TR-7	Nabil parking	8.44	808	− 28	406	32.8
TR-8	Sluice gate	7.69	787	− 112	392	29.4
TR-9	Birulia Bus Stand Ghat	7.55	1146	− 119	576	29.6
TR-10	Ponchoboti Bus Stand	7.93	1034	− 31	513	30.9
TR-11	Rustumpur Bus Stand Ghat	7.64	1182	− 128	592	28.9
TR-12	Ashulia bus stop bridge	7.86	1493	− 36	739	30.9
TR-13	Kamarpara Bus Stand	7.42	962	− 134	472	30
TR-14	Tongi Ijtema bridge	7.15	886	− 150	442	29.1

maximum samples were within the limit except for sample point TR-10 (near to Rustumpur) and TR-11 (near to BGMEA University). The concentration of Ca^{2+} ranges between 28.59 and 39.47 mg/l with an average value of 33.95 mg/l. According to BDWS [58] and WHO [59], the acceptable limit of Ca^{2+} is 75 mg/l, so all the water samples are within the acceptable limit. The concentration of Mg^{2+} is between 11.10 and 13.58 mg/l with a mean value of 12.27 mg/l. The concentration of K^+ is between 5.21 and 13.26 mg/l (average 10.71 mg/l). BDWS [58] acceptable limit for K^+ is 12 mg/l. Four samples (TR-1, TR-2, TR-6, TR-11) exceed the limit. The major cation trend was $Na^+ > Ca^{2+} > Mg^{2+} > K^+$.

Among the anions, $HCO^{3−}$ is abundant and the concentration ranges between 165.45 and 388.87 mg/l with an average value of 286.63 mg/l (Fig. 11). The highest value is near to Ponchoboti bus stand. According to the Bangladesh Drinking Water Quality Standard [60], acceptable limit of $HCO_3^−$ is 200 mg/l, for Nitrate is 10 mg/l, and for $Cl^−$ is 150–600 mg/l. All the samples of the study area exceed the limit for $HCO_3^−$; only two samples, TR-13 and TR-14, are within the limit. $Cl^−$ varies between 54.81 and 194.07 mg/l with a mean value of 89.41 mg/l. Concentration of $SO_4^{2−}$ is very high than the BMAC, ranging from 52.49 to 289.63 mg/l with a mean value of 192.78 mg/l. The concentration of $SO_4^{2−}$ exceed the standard limit for samples TR-4, TR-5, TR-6, TR-8, TR-10, and TR-11. $NO_3^−$ concentration ranges between 9.63 and 126.93 mg/l with a mean value of 57.80 mg/l. All water samples of the study area exceed the limit except the sample TR-7. The major anion trend is $HCO_3^− > Cl^− > SO_4^{2−} > NO_3^−$.

Minor ($Br^−$, $PO_4^{3−}$ & $F^−$) and trace elements (Fe^{2+}, Mn^{2+}) have been investigated from the collected water samples of the Turag River. The PO_4 content in the collected water

samples varies from 0.60 to 13.45 mg/l with a mean value of 5.89 mg/l (Fig. 12). The permissible limit of phosphate for irrigation water is 2.00 mg/l [61]. So, $PO_4^{2−}$ values in all water samples except TR-7 were above the permissible limit for irrigation that might be harmful for crop production. $F^−$ Concentration ranges between 0.07 and 0.13 mg/l with a mean value of 0.1 mg/l. According to Environmental Protection Agency (EPA), WHO, and BWQS, the standard of $F^−$ is 2, 1.5, and 1 mg/l, respectively, and from the analysis, it is found that the samples are within the limit. Concentration of Br^- was between 0.07 and 1.58 mg/l with a mean value to 0.87 mg/l (Fig. 12). Water samples collected from the Turag River contained comparatively less amount of iron (Fe), and the amount varies from 0.07 to 1.14 mg/l with a mean value of 64 mg/l. According to the Bangladesh Water Quality Standard [60], the standard value is 0.3–1 mg/l. All samples are within the limit except TR-1 and TR-14. The major sources of iron are pharmaceuticals, chemicals, pesticides, and industries around the study area. The concentration of Mn in water samples of the Turag River ranges from .006 to .47 mg/l with a mean value of .22 mg/l. According to WHO (0.1 mg/l), all samples exceed the limit except TR-7 and TR-10.

Islam et al. [38] documented that metal concentration in Turag River water is increasing day by day due to solid waste dumping and industrial effluents. Tahmina et al. [62] also showed that most of the physicochemical parameters of Turag River water exceed the standards suggested by WHO [59]. Banu et al. [63] analyzed Turag River sediments to assess heavy metal concentration. Interestingly, he also found the frightening upraise of heavy metals in Turag River water sediments that were settled from river water suspension.
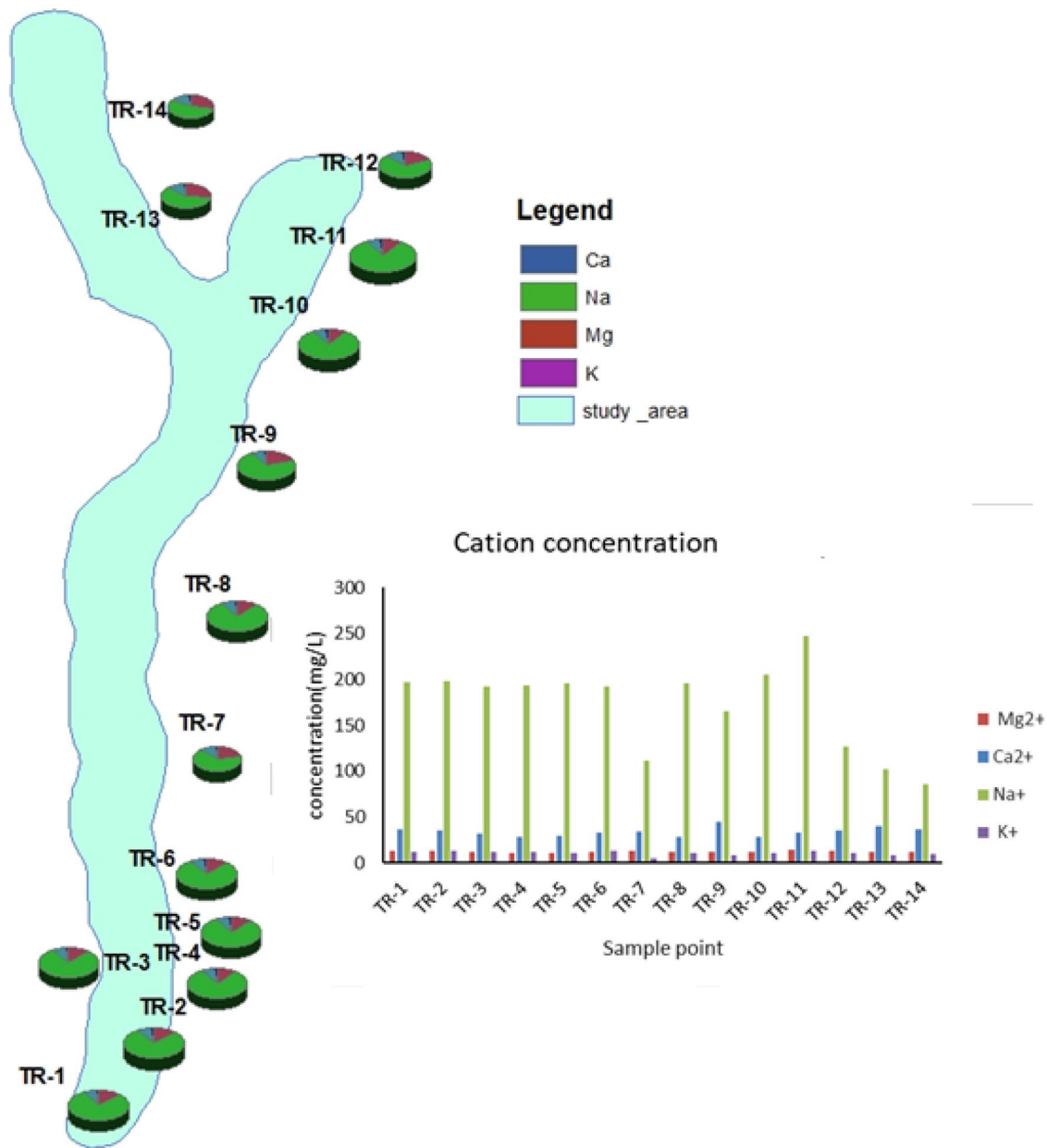
Fig. 10 Spatial distribution of cation concentration of collected water samples from the study area

4.3 Land surface temperature (LST)

LST is increasing day by day due to unplanned and rapid urbanization. The study area is within the temperature range of 15–20 °C to 20–25 °C from 1989 to 2019, and indicates healthy vegetation during the year 1989 and 2000 (Fig. 13). There is a temperature range of 15–20 °C in 2009 and 2015 which shows a lower temperature than any other years because of seasonal variations, solar radiation, and meteorological fact. Most of the higher temperatures have been observed in the land filled sites and other industrial zones. Using sand as a landfilling material is very much related to increased urban land surface temperature. The highest temperature range 31–36 °C is shown in the LST Map of 2019 which indicates industrial zone and rapid urbanization. Satellite image-retrieved LST data values are lower than field observed in situ LST because the satellite images are the medium resolution (resampled 30 m) and always gave an average pixel value (Fig. 14). In 1989, the highest temperature is 29.78 °C near Ashulia Bridge and the lowest LST temperature is about 27.13 °C near to Royal city area which is at Mirpur road. In 2000, the highest
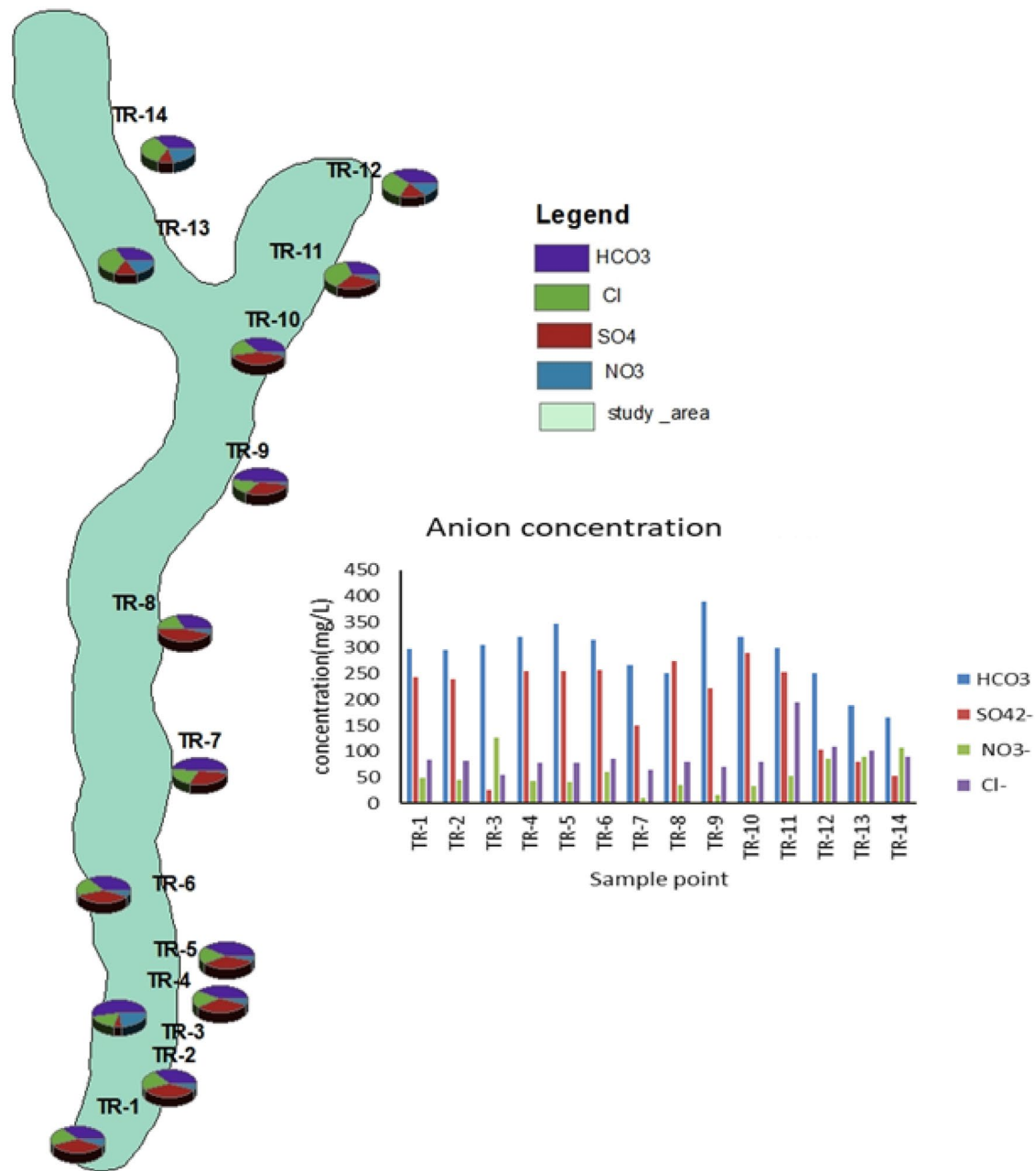
Fig. 11 Spatial distribution of anions concentration of collected water samples from the study area

temperature is about 25.48 °C adjacent to Ashulia Bridge and the lowest temperature is about 20.35 °C near Diabari Bazar Ghat.

The highest and lowest temperature range value is about 28.97–23.33 °C, 30.32–24.07 °C, 30.19–25.68 °C, respectively, in 2009, 2015, and 2019. The ground observation shows that the temperature is highest at 30.19°C in 2019 near to Ponchoboti bus stand and Ashulia Beribadh and lowest at 28.9 °C near to Rustumpur bus stand. From the image processed data of 2019, it shows that the

highest temperature of the water is 30.19 near Ashulia and the lowest temperature is 26.07 °C near to Rustumpur bus stand. The average temperature of the water from filed observed data is 30.05 °C and from image processed data is about 28.32 °C. Ferdous and Rahman [64] also suggested the positive correlation between urban expansion and increasing land surface temperature (LST) in Dhaka city. Chaudhuri and Mishra [65] compared LST and landcover dynamics both in India and Bangladesh in the Ganges–Brahmaputra delta. They urged proper LULC
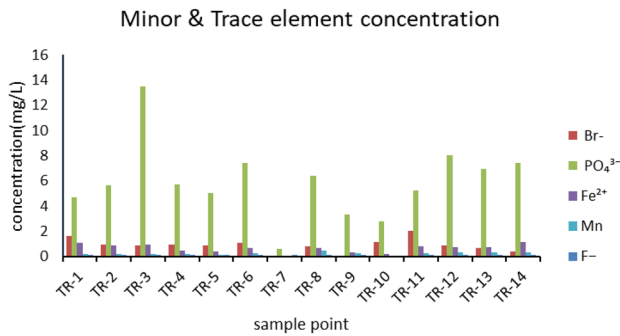
Fig. 12 Concentration of minor and trace elements (mg/l) within the collected water samples from the Turag River
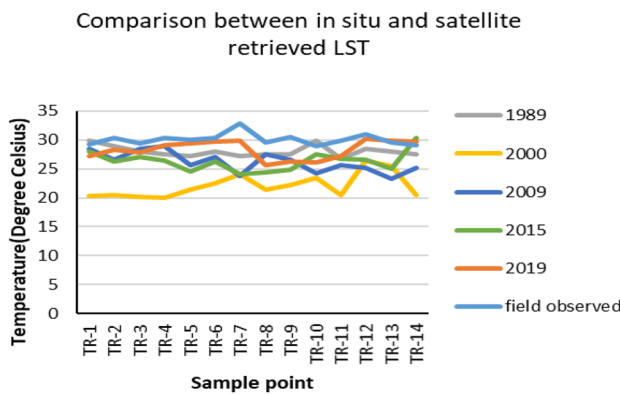

Fig. 13 Satellite image-retrieved LST and in situ measured temperature in the sampling points

management within the delta and river floodplain to protect environmental health and reduce LST. LST of Turag River floodplain also suggests proper LULC management to protect Turag environmental health.

4.4 Relation among LULC, LST, and water quality–quantity

LULC mapping by time series analysis from satellite images suggests that LULC pattern controls the water quality in different parts of the river. The results show that Turag flood plain area has been experiencing an increase in urban and industrial growth, but forest and grassland are rapidly reduced. This increasing urban expansion and unplanned industrialization are responsible for discharging huge municipal and untreated effluents to the river water (Fig. 15). These development activities are destroying the natural river ecosystem by huge water withdrawal and the infilling river area. It is evident that urban development is more intensive in the southern downstream part of the Turag River. Water samples collected from downstream of the study area show a high concentration

of specific cations and anions with minor and trace elements in comparison with other parts of the river. It can be validated by using water quality data from the respective year of LULC map. From 1989 to 2019, the river floodplain area has been undergone a huge change in LULC showing the enlargement of the industrial zone and urbanization with simultaneous reduction of water bodies and vegetation. This human-induced LULC change has been triggered by the LST of the floodplain area. The high LST has also been observed in the river water due to the untreated hot wastewater discharge into the river. Furthermore, the water quality deteriorated owing to the unplanned industrialization on the Riverbanks.

Rahman et al. [8] and Banu et al. [63] studied the physicochemical properties of Turag River water. They found low EC and TDS values along with less cation and anionic concentration compared to the results of the present study. We can correlate this concentration with LULC map of 2009 or 2015. It can be better represented by correlating water quality data of 1989, 2000, and 2009 with the LULC map of the respective years. However, there is a strong correlation between LULC and water quality.

Similarly, the LST of the study area was examined due to the positive correlation between urbanization and increasing LST. It can be validated by using LST in the flood plain area. The increasing LST in the flood plain area is owing to the rapid industrialization. LST is higher in urbanized and industrialized regions rather than bare lands and vegetated areas. Urbanization is most prominent in the upstream region, but industrial developments are more evident in the downstream regions. Both areas around the river flood plain show abnormally higher LST. Interestingly, the LST of the study area provides an important clue to the presence of industrial effluents in the river channel. Generally, water shows a lower temperature than terrestrial regions [24], Alavipanah et al. [66] but different parts of the Turag River channel mainly in the downstream area demonstrate higher LST. In situ water temperature data from field observation also suggest warmer water in this region.

5 Conclusion

The study has been attempted to evaluate the changes in water quality and quantity with LULC in the floodplains of the Turag River. The classification approaches depict that the water body is decreasing day by day. It has also been observed that the vegetated area has been decreased over these years which are about 60% in terms of percentage. Urban growth and simultaneously reduced vegetation are responsible for degrading water quality in the Turag River. The water is highly polluted and detrimental to human health and the aquatic
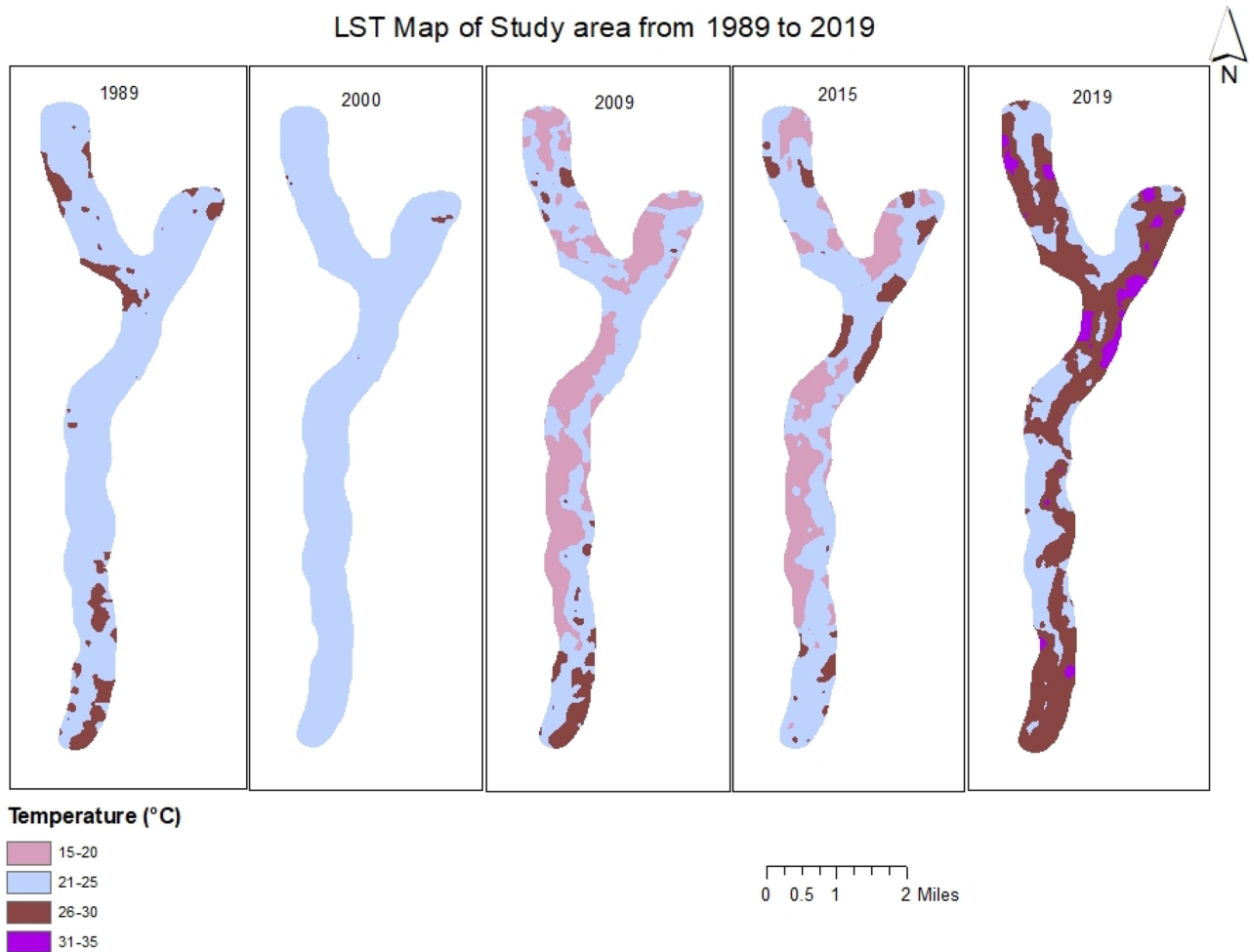
Fig. 14 Comparison and distribution of retrieved LST from 1989 to 2019 using multispectral Landsat satellite images

ecosystem. It is very crucial to revive the river by reducing the degree of pollution by implementing laws and raising public awareness. Among the physicochemical parameters, nitrate & bicarbonate exceeded the acceptable limit that is due to the unplanned discharge of various industrial effluents. The study suggests that the water is not safe for drinking and household uses and must be treated before this kind of utilization. Based on the findings of this research, the level of pollution should be reduced by taking effective measures immediately and more concentration should be paid to the environmental problems of the River. It is very crucial to revive the river by reducing anthropogenic activities by

implementing laws and raising public awareness. It is only possible by creating awareness among the people regarding the consequences of this deteriorating environmental condition of this river. Otherwise, it will follow the fate of the Buriganga River, Dhaka, that is the most polluted river in Bangladesh. The outputs of the study will play a significant role in urban river management. The study also provides a key message to the policymakers regarding the necessity of proper and sustainable floodplain management.
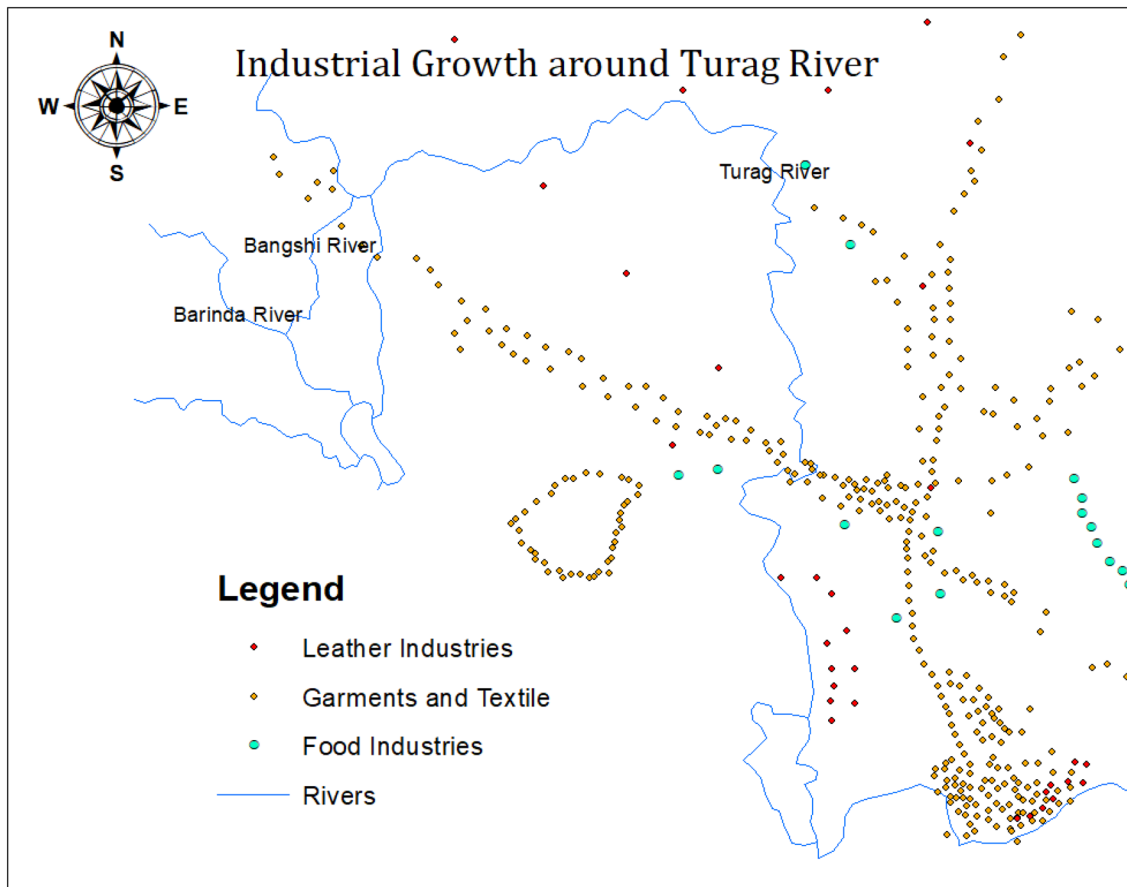
Fig. 15 Spatial distribution of leather, garments, textile, and food industries around the Turag River

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest

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